Steam Surface Pasteurization of Beef Frankfurters

M. CYGNAROWICZ-PROVOST, R. C. WHITING, and J. C. CRAIG, JR.

ABSTRACT

Meat and poultry products are sources of foodborne bacterial contamination. We used flash steam heating followed by evaporative cooling to quickly reduce bacterial contamination on the surface of beef frankfurters without degrading appearance. The rate of heat transfer was studied by measuring surface temperature in a pressure chamber during steam heating. Quality changes were determined by measuring color and weight as functions of steam temperature and treatment time. Efficacy of the process was verified by microbiological experiments using *L. innocua.* Treatment times of 30–40 sec at 115–136°C gave a 4 log reduction in bacterial counts on the surface without severely affecting color or weight. After long-term storage at 6°C and at 19°C, levels of bacteria on inoculated frankfurters remained reduced and there was no difference between treated and untreated products in color or weight.

Key Words: meat, steam pasteurization, microbes, listeria, frankfurters

INTRODUCTION

THE SURFACES of meat and poultry can contain detectable levels of bacterial contamination. A pathogen of increasing concern is *Listeria monocytogenes.* It is widespread in nature, and has been isolated from various fresh foods such as milk, meats, fish, poultry and vegetables. It has also been found on processed meats, such as frankfurters (Wenger et al., 1990). The organism has been shown to survive heating (Mackey and Bratchell, 1989) and refrigeration (Wilkins et al., 1972).

Several approaches have been suggested to reduce the levels of microbial contamination on meat and poultry during processing. The application of chlorine (Villareal et al., 1990), acid (Lillard et al., 1987) or fatty acid (Quartey-Papafio et al., 1980) dips has been used to sanitize meat and poultry carcasses. This approach requires relatively long treatment times (2–120 min) and typically only small reductions (i.e., 2–3 log cycles) in bacterial count are achieved. Also, these dips had a serious detrimental effect on the appearance and sensory quality of the products. Ultrasonic energy (Sams and Feria, 1991) and ultraviolet radiation (Stermer et al., 1987) treatments have also been considered, but were ineffective for products with irregularly-shaped surfaces.

In contrast to the previous approaches, our work investigated the use of flash steam heating followed by evaporative cooling to quickly reduce bacterial contamination on the surface without introducing notable degradation of products. The objective was to design a fast process that could be incorporated into high-speed meat and poultry processing lines. We studied beef frankfurters, because they are cooked products and have a smooth regular shape. Despite the fact that they are cooked, they are at some risk for bacterial contamination. During processing, the microbial load in frankfurters is undetectable when they exit the smokehouse (Zaika et al., 1990), but they may become contaminated at detectable levels during the peeling step, when the casing is removed. An outbreak of listeriosis was attributed to consumption of uncooked turkey frankfurters (Wenger et al., 1990). Another objective was to determine conditions that would give a 4 log reduction in the population of *Listeria monocytogenes* on the surface. This organism is more heat resistant than other common food pathogens, such as *Salmonella* (Mackey and Bratchell, 1989), and therefore these operating guidelines should represent a margin of safety.

The authors are with the U.S. Dept. of Agriculture, Agricultural Research Service, Eastern Regional Research Center, 600 East Mermaid Lane, Philadelphia, PA 19118.

MATERIALS & METHODS

Pasteurization system

The frankfurters were treated in a small pasteurizer, designed and constructed in our facility (Fig. 1). The treatment chamber consisted of a small diameter (50.8 mm) stainless steel tube, equipped with five bare wire thermocouples (Teflon-coated, Type E, 0.25 mm diam). The tips of the thermocouples protruded through the bottom of a Teflon mesh support. This support held the frankfurters in direct contact with the thermocouple tips. The difficulties encountered when experimentally measuring surface temperatures are well documented (Houghten and Olson, 1949). We used very small diameter thermocouple wires so that heat transfer to the surface would not be disturbed, and heat conduction away from the surface would be minimized. The thermocouples were connected to a multiplexer board to amplify and condition the signal, and the multiplexer was in turn connected to a high-speed data acquisition board installed in a microcomputer. Three thermocouples were in contact with the product surface, and two were exposed to the chamber conditions.

A configuration of valves and switches was designed to rapidly fill and empty the chamber. The valves were controlled through a digital input/output (I/O) board installed in the microcomputer. The I/O board was connected to a solid state relay board which could turn the power to the valves on or off depending on the signal from the microcomputer. A high-capacity (i.e., 100 cfm at ≈74 cm Hg) vacuum pump (Ingersoll-Rand) was used to evacuate the chamber before and after introduction of the steam. The inlet steam pressure was set using a regulator.

To begin the experiments, beef frankfurters (one national brand was used for all experiments) were weighed and placed in the treatment chamber. The chamber was evacuated for 15 sec and the product was exposed to steam at a set pressure until the desired treatment time was reached. The steam was then evacuated for 10 sec, quickly cooling the product. The product was removed, weighed, vacuum packaged and stored in a refrigerator until color measurements could be made. Four steam temperatures (i.e., 115°C, 121°C, 128°C, and 136°C) and six treatment times (5, 10, 15, 20, 30, and 40 sec) were investigated. Ten samples were treated at each condition.

Color measurement

The Hunter L-a-b values for the products were measured before and after treatment using a Pacific Scientific color spectrophotometer. Source F1 (simulated fluorescent light) was used to illuminate the sample. Five equally spaced points were measured along the length of each sample.

Microbiological experiments

Microbiological experiments were conducted to verify the efficacy of the process. Since the work was done in our food processing pilot plant, safety considerations dictated that a pathogenic strain could not be used. *Listeria innocua,* a non-pathogenic strain, was utilized in all experiments (SA3-VJ, Buchanan et al., 1989). It has similar, but slightly larger, D-values than *L. monocytogenes* (Foegeding and Stanley, 1991). The organism was grown in 100 mL BHI/300 mg glucose solution at 28°C for 18 hr. The frankfurters to be inoculated were

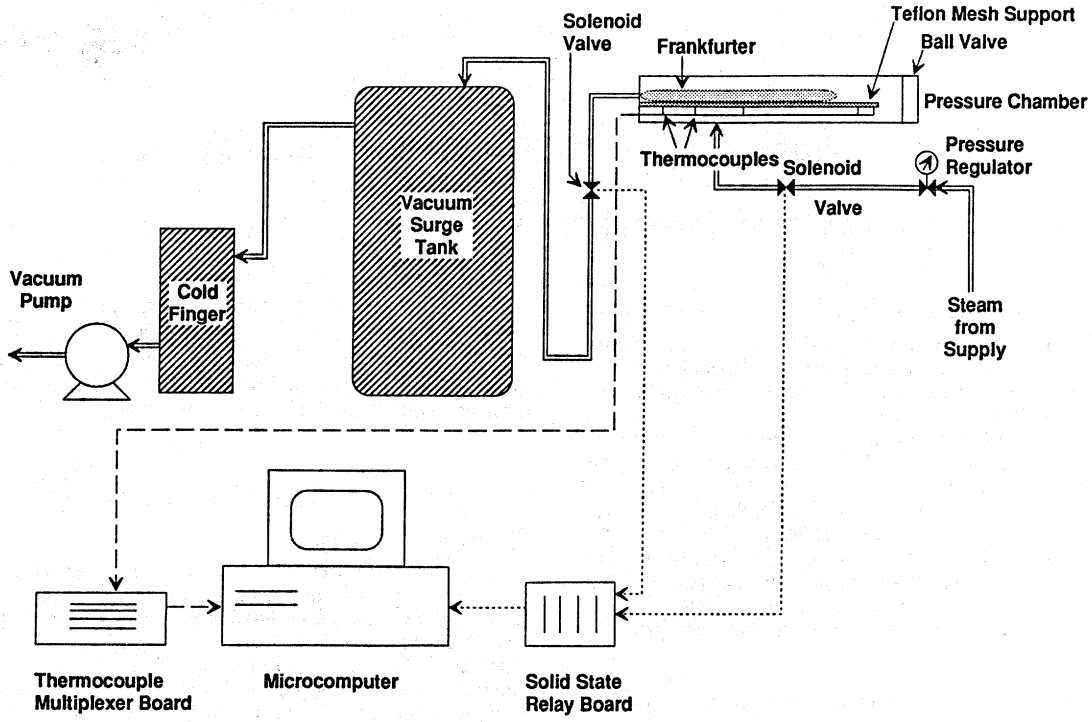

Fig. 1—Diagram of surface pasteurization apparatus.

placed in a sterile stomacher bag, the culture was added and the bag was slowly agitated for 10 min to allow adequate coverage of the surface. The frankfurters were allowed to dry for 15 min under a biological hood. Immediately after heat treatment, the frankfurters were placed in a sterile stomacher bag and the bags were kept on ice until plates could be prepared. To determine the population that remained after treatment, 100 mL of sterile 0.1% peptone water was added to the stomacher bags containing the treated frankfurters, and the bags were shaken for 2 min. The solution was then diluted and plated onto triptose agar. This procedure has been shown to remove nearly all of the bacteria from the surface of frankfurters (Palumbo and Williams, 1991). Duplicates were run at each condition, and two runs were completed.

The bacterial populations on three inoculated and three uninoculated controls were measured as described. The inoculated controls contained on average 1.02×10^7 colony forming units (CFU)/mL and uninoculated controls contained no colonies.

Storage tests

Storage tests were conducted at two different temperatures: 19°C and 6°C. Frankfurters were inoculated with *L. innocua* at 10^3 CFU/mL (average plate count = 3.16×10^3 CFU/mL) and were treated for 32 sec at 136°C. The samples were then vacuum packaged and stored in incubators at 6° and 19°C. Periodically, the samples were removed and analyzed for total aerobic plate count, weight loss and color change. Four different sample types were studied: uninoculated, untreated; uninoculated, treated; inoculated, untreated and inoculated, treated.

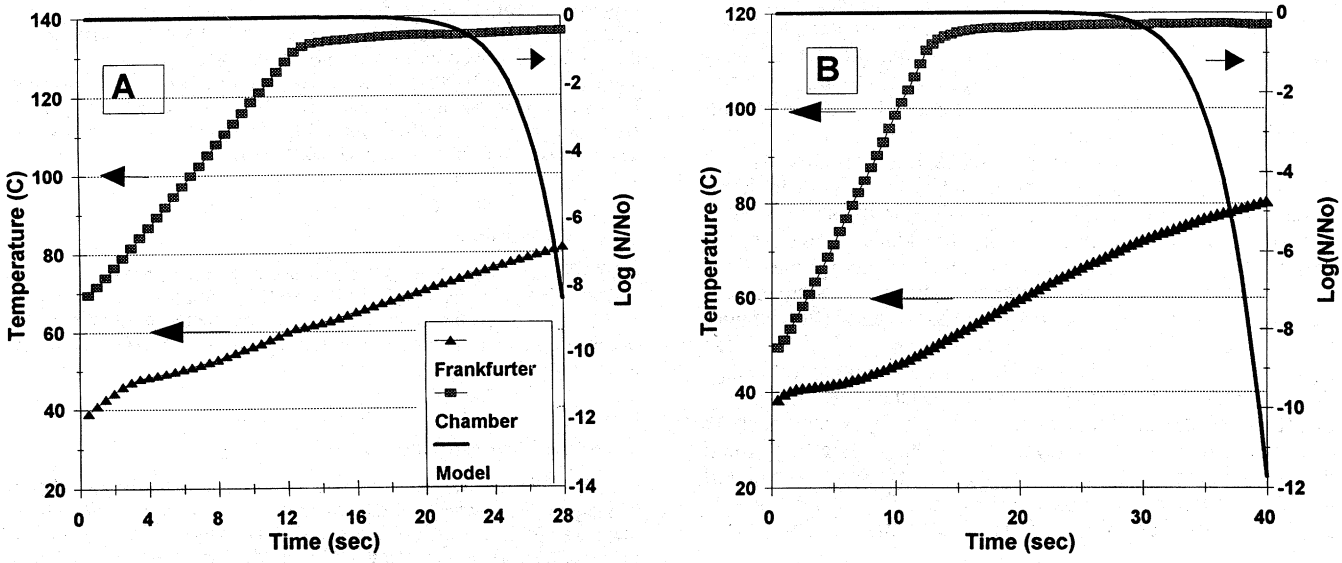

Fig. 2—Frankfurter surface and chamber temperatures during pasteurization process. Data points are the average of 10 experiments. Also given is the fraction of bacteria remaining of the surface as computed by Eq. (2). N_o is the initial population of bacteria (CFU/mL) and N is the population of bacteria at the current time (CFU/mL). (A) Steam temperature = 136°C; (B) Steam temperature = 115°C.

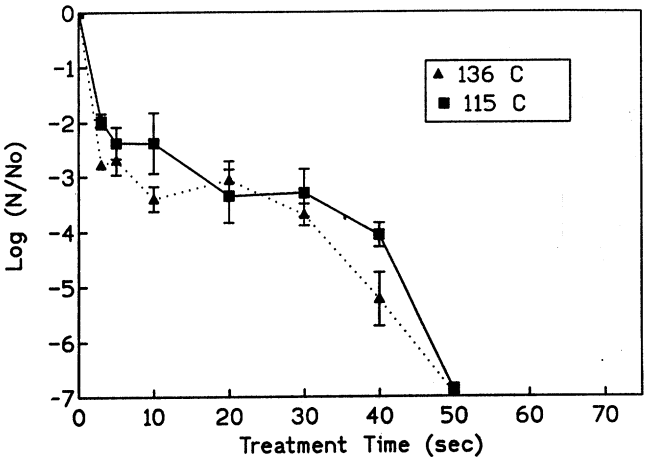

Fig. 3—Population of Listeria innocua surviving after surface pasteurization as a function of treatment time and steam temperatures. N_o is the initial inoculum of bacteria (CFU/mL) and N is the population of bacteria at the current time. Values are the average of two experiments, two samples per experiment. The error bars represent 95% confidence limits.

RESULTS & DISCUSSION

UNLIKE MANY other heat transfer processes presented in published reports, ours was not a steady-state process. The "come-up" time was an integral part of the treatment, since the goal was to keep the treatment time as short as possible to minimize product degradation. The product surface temperatures and chamber temperatures observed during this treatment were compared (Fig. 2A-B).

The treatment time necessary to obtain a 4-log reduction may be estimated using published D-values for *L. monocytogenes*. Gaze et al. (1989) presented thermal death data for *L. monocytogenes* in beef, chicken and vegetable homogenates and computed D-values for this organism at 60–70°C. Since the highest D-values were reported for beef steak homogenates, we used those to obtain conservative estimates. Assuming Arrhenius kinetics, the resulting expression for the rate constant, k, was determined to be

Table 1—Weight loss of beef frankfurters as a function of treatment time

Treatment time (sec)	Percent[a] weight loss
0	0.0
5	0.50 (±0.03)
10	0.76 (±0.04)
15	0.92 (±0.06)
20	1.09 (±0.06)
30	1.45 (±0.15)
40	1.63 (±0.09)

[a] Percentages are averages for four runs (at four different steam temperatures) with 10 samples each run. 95% confidence limits, as determined by the student's t-test (Hoel, 1976) are in parentheses.

$$\ln(k) = 126.5094 - \frac{43949}{T} \quad (1)$$

Since the pasteurization process in this case does not take place at a constant temperature, the integral form of the first-order thermal death expression was used:

$$\ln\left(\frac{N}{N_0}\right) = -\int_0^{t_e} k\{T(t)\}dt \quad (2)$$

In this expression, t_e is the total exposure time. Since the surface temperature was measured as a function of time, the above expression could be integrated to estimate the required treatment time. We computed the time for a 4D reduction to be 36 sec with 115°C steam and 26 sec with 136 steam°C. The thermal death curves were predicted for averaged experimental temperature histories (Fig. 2A-B).

To verify these estimates, frankfurters were inoculated with the test organism and treated between 3 and 50 sec at 136 and 115°C. The logarithm of the fraction of *L. innocua* bacteria surviving was plotted as a function of the treatment time (Fig. 3). To obtain a 4D reduction, a 32 sec treatment was required at 136°C and a 40 sec treatment was required at 115°C. Note that these times were slightly longer than the predictions. The discrepancy may result from either differences in the strain or

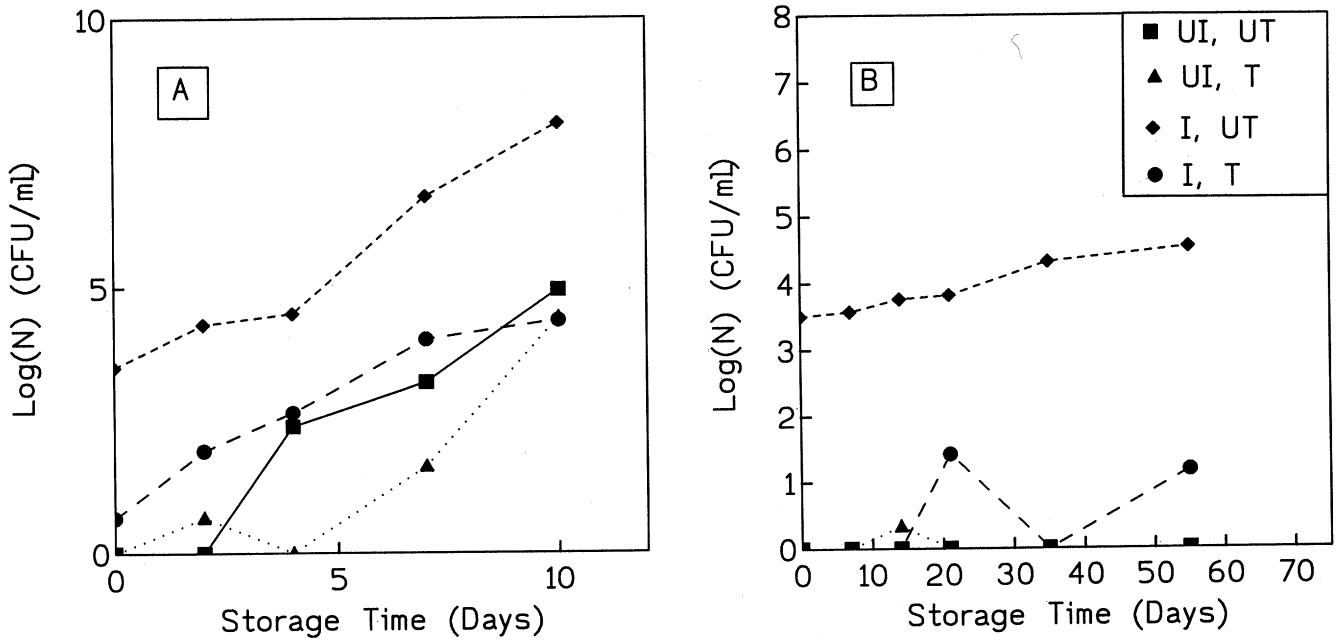

Fig. 4—Total aerobic plate counts on the surface of treated and untreated frankfurters. UI, UT = uninoculated, untreated; UI, T = uninoculated, treated; I, UT = inoculated, untreated, I, T = inoculated, treated. Values are the average of two samples. (A) 19°C; (B) 6°C.